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SWiM in Marine Sanctuaries: The Challenge of Monitoring a System of Protected Areas

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A System-Wide Monitoring (SWiM) program is currently in development to provide an approach for integrated design, implementation, and reporting for the National Marine Sanctuary System. It will serve individual marine sanctuaries, regional networks of sanctuaries, and the collective system. It allows for tailored monitoring in all sanctuaries, providing information critical to management, while also contributing to and benefiting from other local, regional, and national monitoring programs.

Managing the natural resources of a protected area is generally accomplished by controlling the human activities that affect them. Seldom are activities undertaken to directly manage the resources themselves (with some exceptions, such as cases involving habitat restoration and stock enhancement). Critical to effective management is knowledge about the structure and function of ecosystems, the stresses affecting them, and how the resources and processes are changing as a result of the stresses. Such understanding is achieved through active characterization, monitoring, and research programs.

The National Marine Sanctuary Program (NMSP) protects the biodiversity, ecological integrity, and cultural legacy of 13 marine sanctuaries covering over 47,000 km² of coastal U.S. and territorial waters. It also administers the Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve (NWHICRER), which alone covers about seven times this area throughout that remote archipelago. All these areas protect vastly differing seascapes, including rocky coasts, offshore banks, kelp forests, estuaries, hard and soft bottoms, canyons, segments of whale migration routes, coral reefs, and mangroves.

Individual sanctuaries require comprehensive monitoring of the status and trends of natural resources and human uses as they affect water, habitat, and living resource quality. Information at appropriate levels of resolution is necessary to support management decisions. For some resources, processes such as migration and larval dispersal dictate that monitoring efforts extend beyond the existing sanctuary boundaries. For some resources, networks of sanctuaries must work together, or even regionally, to track and report on

the condition of shared resources and changes in processes, events, and levels of human use. As a national system of sanctuaries, the NMSP must also be able to report on progress regarding mandated responsibilities of resource protection, necessitating national coordination of monitoring programs.

The primary goal of SWiM is to provide for the consistent application of a robust conceptual framework, design model, and reporting strategy to enable the evaluation of status and trends in trust resources and activities that affect them. Fig. 1 shows the relationship between the various aspects of the monitoring framework and the management and policy that it supports. It also shows the basic steps that can be used to design a monitoring program for a sanctuary, a group of sanctuaries, or even for specific types of natural resources (e.g., seabirds or migratory whales).

Three distinct phases are considered fundamental to an effective monitoring program (see boxes under "Sanctuary Monitoring" in Fig. 1). The first two involve program design, the third acquisition, analysis and reporting of information. The first phase, "Objectives to Metrics": on Fig. 1, requires a clear understanding of the site's management objectives and asking specific questions based on existing threats to priority resources. In addition, there are questions that apply to all sanctuaries. Though not as specific as those posed at smaller spatial scales, the 14 "system questions" below are considered in the course of development of site-based monitoring programs in all sanctuaries. They relate generally to the quality of *water*, *habitat*, and *living resources* - the three principal areas of interest common to all marine sanctuaries that protect natural resources. The system questions are as follows:

Water Quality

1. Are specific or multiple stressors negatively affecting sanctuary water quality?
2. What is the eutrophic condition of sanctuary waters and how is it changing?
3. Do sanctuary waters pose a human health hazard?
4. What are the levels of human activities that may influence water quality and how are they changing?

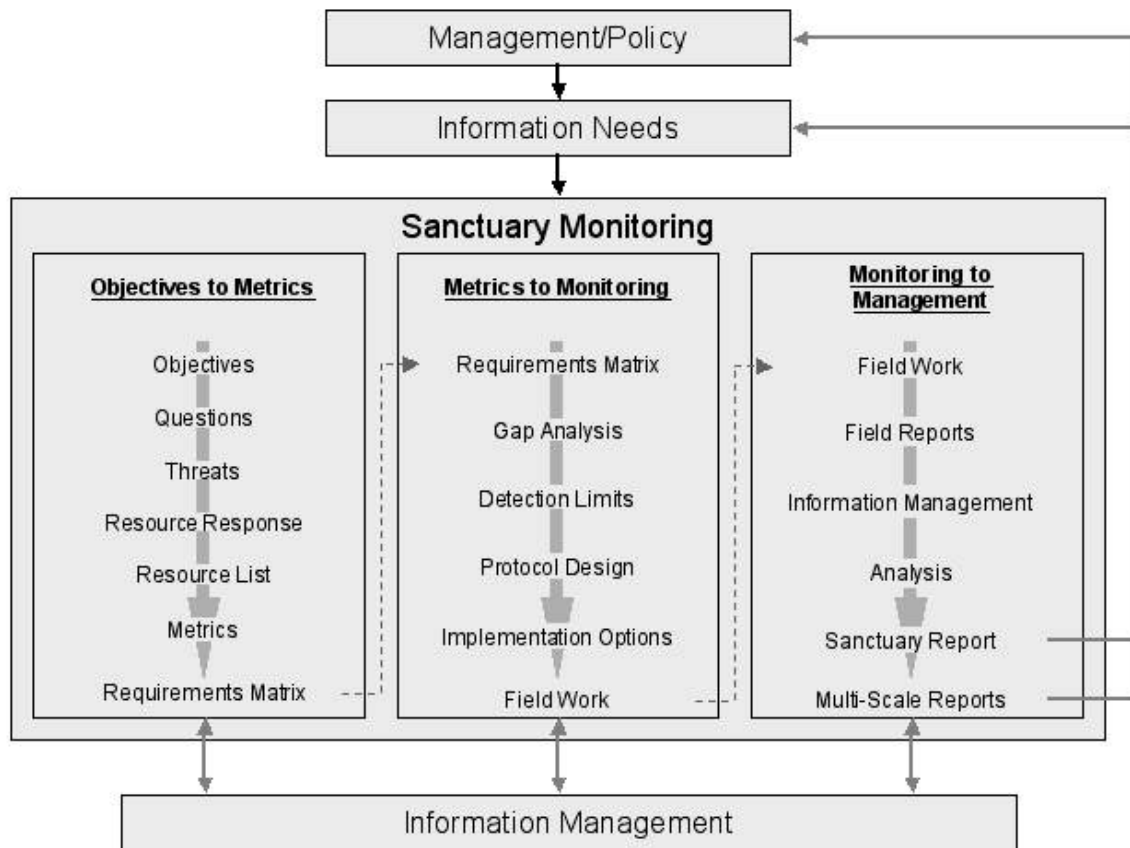


Fig. 1. Framework for System-Wide Monitoring (SWiM) in the National Marine Sanctuary Program, showing the key steps used to develop monitoring at selected spatial scales, and the feedback of monitoring information to resource managers and policy makers.

Habitat Quality

5. What is the abundance and distribution of abiotic and biogenic habitats and how are they changing?
6. What is the structural condition of habitats and how is it changing?
7. What are the levels of contaminants in habitat resources and how are they changing?
8. What are the levels of human activities that may influence habitat quality and how are they changing?

Living Resource Quality

9. What is the status of biodiversity and how is it changing?
10. What is the status of extracted species and how is it changing?
11. What is the status of key species and how is it changing?

12. What is the status of non-indigenous species and how is it changing?
13. What is the condition or health of key resources and how is it changing?
14. What are the levels of human activities that may influence living resource quality and how are they changing?

Once the appropriate questions are posed, resource specialists can identify the most significant threats and the most likely environmental responses to those threats. An important outcome of the first phase of planning is a “requirements matrix” that defines, generally in tabular form, what resources require assessment and what specific measurements must be made for each.

The requirements matrix becomes the initial element of the second planning phase (“Metrics to Monitoring” on Fig. 1). After identifying the types of measurements to be made, sanctuary staff and

selected experts determine whether existing programs already conduct these assessments, and whether they are measured at appropriate scales and resolution, as established by sanctuary management. The critical step of designing appropriate sampling protocols then ensures, a process that requires consideration of field capabilities, identification and prioritization of key indicators, sample site selection, statistical design, and cost limitations. When necessary, pilot efforts to obtain preliminary information on environmental characteristics (e.g. expected densities, diversity, temporal and spatial variance, etc.) are conducted. A number of implementation options are then generated, each of which clearly identifies, among other things, levels of sampling, expected detection capabilities (i.e., statistical power), participating partner responsibilities, timelines, milestones, and costs.

The third phase, "Monitoring to Management," (see Fig. 1) involves the implementation of the selected option, resulting in field sampling, data analysis, and reporting. The primary, and most immediately useful products of this effort are reports that provide information to local managers on the status of protected resources and, in some cases, the outcomes of specific management actions. With cooperative multi-site planning efforts and efficient information management, however, local information from more than one sanctuary can be combined to contribute to regional and national reports that document environmental conditions at larger scales.

Feedback at every scale can then be used to inform decision-making and guide policy.

It is not the goal of SWiM to collect the same measurements in all marine sanctuaries. The most important need is to provide a consistent, efficient, and effective approach to the design, implementation, and reporting for individual marine sanctuaries. The design process allows for tailored monitoring in all sanctuaries, which both provides information that is critical to management and contributes to and benefits from other local, regional, and national monitoring programs. SWiM also provides a means to design monitoring programs to address, for the first time, questions related to networks of sanctuaries, specific issues, selected resource types, and the sanctuary system as a whole.

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